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MINING AND WATER-CONTROL METHODS AT THE CHIEF LEAD-ZINC MINE, CHIEF CONSOLIDATED MINING CO., JUAB COUNTY, UTAH

By W. E. Young

United States Department of the Interior — May 1958

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MINING AND WATER-CONTROL METHODS AT THE CHIEF LEAD-ZINC MINE, CHIEF CONSOLIDATED MINING CO., JUAB COUNTY, UTAH

by

W. E. Young[1/]

CONTENTS

	Page
Summary and introduction	1
Acknowledgments	1
Early history of the district	1
History of unwatering operations	4
General geology and ore deposits	7
Exploration	9
Sampling and estimation of ore reserves	9
General mine operation	9
Mining	12
Ventilation	12
Shaft sinking	14
Electric power	15
Pumping system	15
Costs	20

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ILLUSTRATIONS

Fig.		Page
1.	Location map, Chief Consolidated Mining Co., Juab County, Utah	2
2.	Property map	3
3.	Section through underground mine workings	8
4.	Sections of main winzes below water level	10
5.	Hoist installation at 1800 level, 18-411 winze	11
6.	View of typical stope	11
7.	Idealized section of mine workings	13
8.	Isometric view of hydro clamshell shaft mucker	16
9.	View of transformer bank, 1800-level substation	17
10.	View of pump station, 2300 level	17
11.	Plan of pumping layout, 2300 level	18

TABLES

1.	List of pumps in the Chief mine	19
2.	Calculation of water pumped per ton of ore mined, June 1954	19
3.	Summary of underground costs per ton, December 1954 and year 1954, based on tons of ore hoisted	20
4.	Summary of indirect expenses and total cost per ton, December 1954 and year 1954, based on tons of ore hoisted	21

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SUMMARY AND INTRODUCTION

This paper describes operations of the Chief Consolidated Mining Co. at the Chief mine in the Tintic district, Juab County, Utah, where the outstanding problem is water control; the unique pumping methods employed are featured in this report.

The ore bodies in this district occur as long, narrow shoots along fault fissures, usually in the Bluebell dolomite of Ordovician age. Oxide ores predominate above the 1800 level, which is also the natural water level. Sulfide ores containing lead, zinc, silver, and gold extend below the 1800 level. The mine is developed by vertical shafts and winzes, from which drifts are driven to the ore bodies. In the lower levels of the mine these drifts extend long distances from the shafts or winzes because of the relatively low dip of the ore shoots. The mine has been worked to the 2800 level and the 18-411 winze extends to the 3080 level.

Pumping, one of the major cost items, is conducted in stages, and 6,500 to 7,000 gallons of water per minute is discharged into a permeable channel at the 1800 level.

Information for this paper was obtained between 1951 and 1955 as the result of inspections of a joint company-Government project.

ACKNOWLEDGMENTS

The author acknowledges the cooperation of executives and staff officials of Chief Consolidated Mining Co., who supplied the technical data and other information for this report. Special acknowledgments are made to Cecil Fitch, Jr., president and general manager of the company; John G. Hall, former general superintendent; Robert E. Steele, former chief engineer; and Max Evans, geologist.

EARLY HISTORY OF THE DISTRICT

The Tintic district, one of the important gold-silver-lead-zinc-copper producing areas of Utah, has yielded ores valued in excess of $450 million. The district was organized in 1870, and by 1871 production was coming from the Eureka, Silver City, and Diamond camps. The Chief mine is one of the later mines developed in the district (figs. 1 and 2).

The Chief Consolidated Mining Co. was organized in 1909. The first work consisted of retimbering and deepening an existing 800-foot shaft. During the period 1909-18, ores were mined between the 600 and 1800 levels; the 1800 level is the lowest one above the permanent water table. By 1916 plans were being made to mine ores below the water table.

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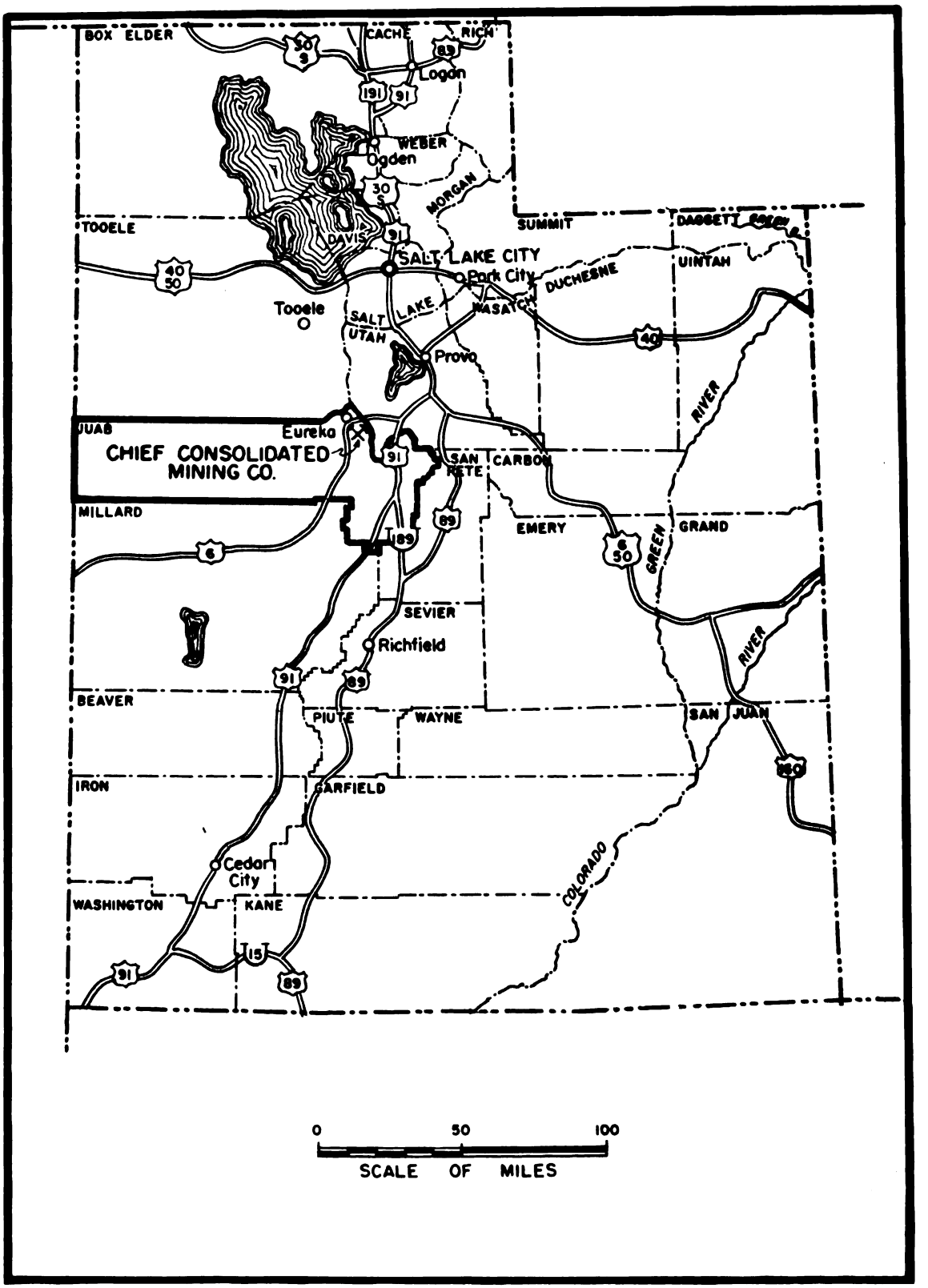

Figure 1. - Location map, Chief Consolidated Mining Co., Juab County, Utah.

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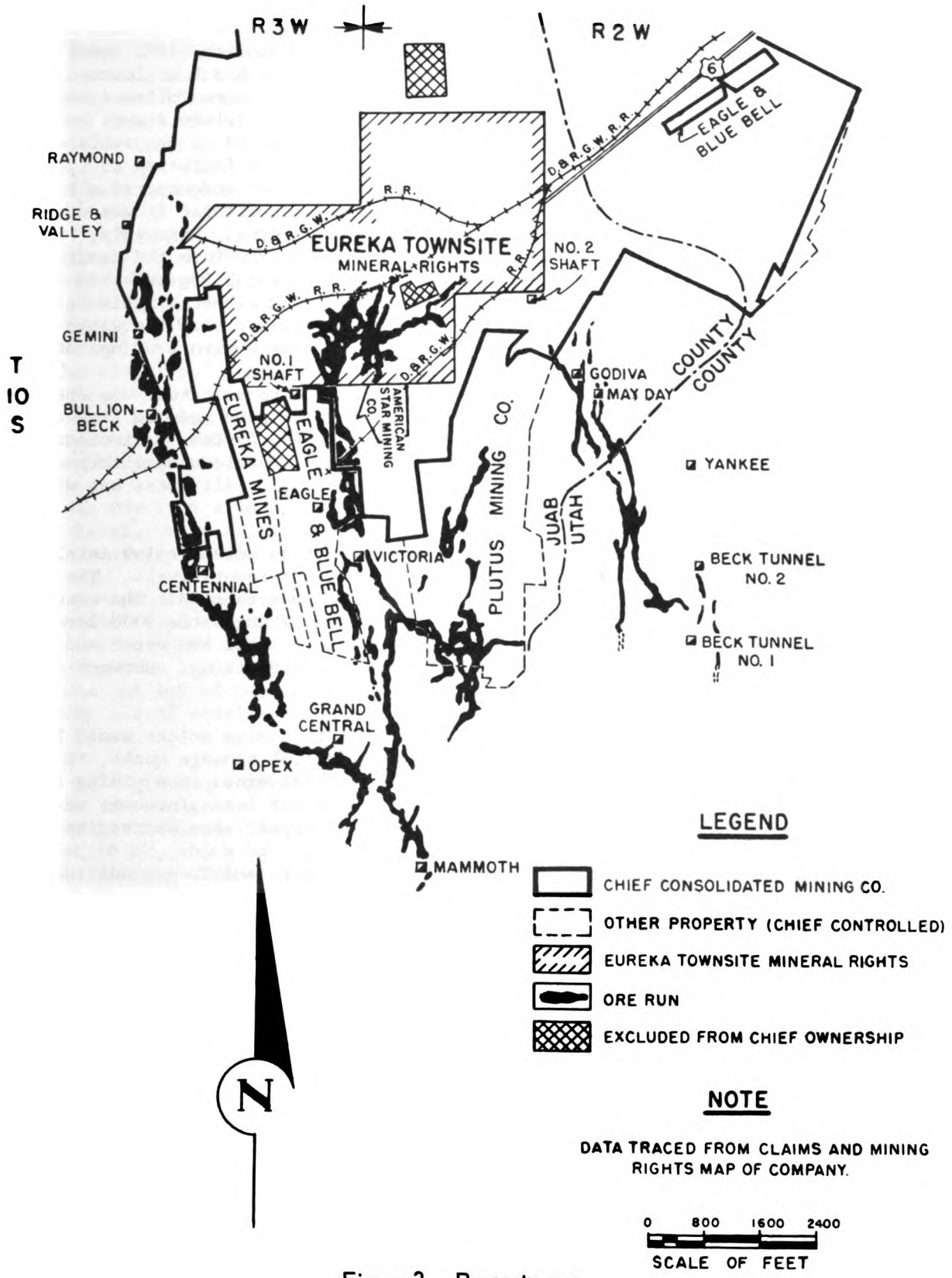

Figure 2. - Property map.

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HISTORY OF UNWATERING OPERATIONS[2/]

Encouraging mineralization encountered in development below the 1800 level resulted in installation of a pumping system. By 1919 the water had been lowered to the 1900 level by pumping to the surface in five stages. Ores were followed downward in various places below the water table by the use of air-driven sinker pumps and by pumping into the central disposal system, which discharged at the surface. By 1921 the 2000 level was reached, and the flow from the pumps increased to 1,000 g.p.m. About this time, an exploratory drift on the 1600 level encountered a natural cavern approximately 2,000 feet from the shaft. As an experiment it was decided to attempt to fill this cavern by pumping water into the opening. Strangely, the cavern did not fill; thus it was decided to pump the entire flow into the cavern. Sodium fluorescein salt was added to determine if the water was being returned to the mine and recirculated. No trace of return water was found either by this color test or by subsequent tests using other indicators. It appeared that the water was being pumped from a perched water table to another lower than the zone of operation.

Meanwhile, greater depth was being attained, greater lateral extent was opened, and the flow of water was increasing. Unsuccessful attempts were made to find other natural outlets at lower elevations. The size of the pumping system was increased, and pumping routes to the 1600-level cavern were shortened. Various auxiliary winzes were sunk, the deepest of which reached the 2500 level. All water was discharged into the cavern.

In 1927 high mining costs due to pumping, in conjunction with the low metal prices of that period, forced cessation of operations on the lower levels. The pumps were pulled and all equipment except pipe and track was removed. The water rose from the 2500 to the 2200 level in 24 hours; from the 2200 to the 2000 level in 3 weeks; and to the 1950 level in 2 years. Twelve years later the water had risen to within 40 feet of its old level and was still slowly rising. Between 1928 and 1942 mining was confined to areas above the water table.

As a result of the 1942 Government announcement that premium prices would be paid for lead and zinc mined in excess of the producer's 1941 tonnage quota, it was decided to pump the water from the lower levels of the Chief mine. New mining techniques and improved procedures in metallurgical processing of lead-zinc ores made mining of the large known reserves below the water table appear more attractive.

The knowledge acquired from experience in the Chief mine and from conditions in other mines in the district was used in formulating plans for unwatering. The adjoining Gemini mine had been confronted with a pumping problem during a long period of operation. The two mines are connected by a drift on the Chief 1600 level, which corresponds to the Gemini 1400 level. An exploratory drift on the Gemini 1600 level, corresponding closely to the Chief 1800 level, had encountered a similar open cavern 1,100 feet north of the Chief cavern. Following the example of the Chief, the Gemini Mining Co. was also successful in unwatering through this outlet. The possibility of recirculating the pumped water has always been a source of concern, notwithstanding the sodium fluorescein color tests. Inasmuch as the Gemini cavern is 1,100 feet farther from the Chief operations, it was decided to use this cavern, as it appeared that less water would return to the workings.

2/ Hall, John G., History of Pumping at the Chief Consolidated Mine, Eureka, Juab County, Utah: AIME Mining Trans., vol. 184, 1949.

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A generalized section of the main winzes operating below the water level of the Chief mine is shown on figure 4 (p.10). A plan of the pumping arrangement on the 2300 level is illustrated by figure 11 (p. 18). Inasmuch as the 18-411 winze is the main working shaft from which extensive future operations were planned, it was decided to use this opening for the main pumping installation. A system capable of discharging 2,400 g.p.m. into the Gemini cavern at the elevation of the Chief 1600 level was installed, and unwatering operations were begun during August 1942.

The original plan was to unwater the 18-411 winze to the 2200 level (its depth at that time) and then to unwater through "C" sump winze to the 2500 level. A 350-hp., 3,000-g.p.m., submersible-type pump was lowered under water to the 2150 level. At this point an obstruction was encountered in the winze, and the pump could not be lowered. However, the water was lowered to this level, but to permit deeper penetration, it became necessary to unwater through another opening. The "C" sump winze, previously sunk to the 2500 level, was found to be caved and unsafe. Two 350-hp., submersible-type pumps were installed in the 1940 winze, and the water was lowered to the 2300 level. A drift was driven to the location of the 18-411 winze on the 2300 level and a connection made in the winze to the 2200 level. A connection was then made between the 18-411 winze and the "C" sump winze, and unwatering was accomplished to the 2500 level, the deepest one at that time. Unwatering has been continued through the 18-411 winze as the mine is deepened.

In May 1944 a drift was completed to connect the Gemini cavern at the Chief 1800 level. This relieved the pumps of the additional 215-foot head to the 1600 level, and the volume of flow from the pumps increased to approximately 4,000 g.p.m.

Ore production during 1947 was increased to 6,500 tons per month as a result of additional exploration accomplished with funds supplied by the Reconstruction Finance Corporation. The 18-411 winze was sunk to the 2700 level, and stations were established on the 2400, 2500, 2600, and 2700 levels. The pumping system was enlarged to include one set of pumps capable of delivering 3,000 g.p.m. at a 950-foot head and a standby set of equal capacity. Both systems discharged into the Gemini cavern at the 1800 level.

This procedure proved adequate for mining ores a short distance above the 2700 level. However, at a point just above the 2700 level the ore shoots are cut and displaced by the Leadville fault-dike. This structure is an argillized latite dike 1 to 3 feet thick, which has the peculiar effect of damming the waters of the footwall block from the unwatered, mined-out areas of the hanging-wall block. Attempts were made to cross the dike and mine ores in the north block; but, in each instance, the excessive flow of water forced discontinuance. It became evident that the existing pumping system was only adequate to drain the south block to the 2700 level. The water in the north block remained at the 2350 level.

The relationship of the dike and the water levels on either side is not completely understood. It is not known whether the dike acts as a dam to seal the water or if it merely impedes water circulation. The wall rock on both sides of the dike, on the 2600 level, is brecciated Bluebell dolomite. Penetration of the dike in this area resulted in free flow of the water. On levels below the 2600, the wall rock on both sides of the dike is the almost impermeable Opohonga limestone. Penetration of the dike on these levels produced only a small waterflow. Further drifting beyond the dike encountered brecciated Bluebell dolomite, and the flow of water increased. This fact is accepted by the miners as a generalization based on experience; as a result, ores are expected short distances from large waterflows in the brecciated dolomite. It is theorized that the water is largely confined to brecciated zones in which the ores occur.

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During November 1950 the company submitted proposals to the Defense Minerals Administration for exploration of the north block. Encouraged by favorable geologic conditions encountered by diamond drilling, the company proposed (1) sinking the 18-411 winze to the 3100-foot level, driving the 2700- and 3100-level drifts to intersect the downward projection of ore shoots in the north block and (2) installing electrical and pumping facilities adequate to unwater to the 3100 level. A contract was executed with Defense Minerals Exploration Administration, which allowed 1,800 feet of drifting and 300 feet of raising on the 2700 level, 400 feet of sinking in the 18-411 winze, and 1,800 feet of drifting and 1,500 feet of raising on the 3100 level.

Project work was begun during December 1950. On its own account, the company undertook excavation for a hoist room on the 1800 level and installation of a hoist designed for a monthly production of 10,000 tons of ores from the 3100 level and capable of a maximum hoisting depth of 3,000 feet.

Early in 1951 exploratory drifts on the 2700 level were driven through the fault and into ore in the north block. The flow of water soon increased to 7,200 g.p.m., and the newly installed pumping system proved adequate to handle the increased flow. Notwithstanding the decline in metal prices in 1952 and early 1953, favorable conditions encountered north of the fault, both with respect to the grade of ores and the size of ore bodies, served to keep the mine in operation.

As each successively lower level south of the Leadville dike was opened, the quantity of water did not increase appreciably. This anticipated condition occurred north of the Leadville dike after the water table was lowered to the equivalent elevation of the south block. The normal waterflow appears to be approximately 6,600 g.p.m., except that an increase to 7,200 g.p.m. occurs for a period after each successive level is opened.

During the mining above the 2700 level, the main gathering sump was located on this level. After deeper sinking and development of the 2800 level, the water table was lowered to it. Later much of the water was being drained by development on the 2900 level. A sump was constructed on the 2900 level and the water boosted from this sump to the 2700 level sump. The 2900-level pump sump is 12 by 10 by 46 feet in size. An auxiliary sump (18 by 15 by 50 feet) also was constructed to act as standby storage in case of emergency. The 18-411 winze has been extended to the 3079 level. The lowest 79 feet will be used as a pump sump. Development on the 3000 level probably will drain the 2900 level.

Confronted with an excessively high initial development cost, the company applied to the Defense Minerals Production Administration for assistance in a large program to be carried on in conjunction with the DMEA exploratory program. A contract was negotiated, consisting of 8 projects in various localities throughout the mine, aggregating 18,010 feet of drifting, 4,100 feet of crosscutting, 7,800 feet of raising, and 43,200 feet of diamond drilling. The estimated cost for completing this work was $1,133,492.

It was anticipated that the work would develop 423,000 tons of ores on the lower levels, with an average grade of 9.34 percent lead, 9.72 percent zinc, 10.88 ounces of silver, and 0.02 ounce of gold per ton; and 64,500 tons of ores on the upper levels, with an average grade of 2.79 percent lead, 2.82 percent zinc, 0.36 percent copper, 27.06 ounces of silver, and 0.046 ounce of gold per ton. These estimated grade figures were derived from weighted production assays of ores mined from the various channels.

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This program was carried to partial completion with DMPA assistance, and the company then deemed it expedient to cancel the contract and complete the work with company funds.

Sinking in the 18-411 winze was suspended in December 1953 and was begun again in February 1955. In May 1955 it became necessary to again suspend sinking operations just short of the 3100 level. A decision was made to explore the ore zone on the 3000 rather than the 3100 level. This decision was based on evidence that indicated flattening of the dip of the ore shoots.

GENERAL GEOLOGY AND ORE DEPOSITS

The geology of the Tintic district was described by Tower and Smith[3] and later by Lindgren and Loughlin.[4]

The rocks of the district consist of sediments ranging in age from Cambrian to Mississippian, and of Tertiary igneous rocks that are in part rhyolite porphyry and monzonite and in part effusive rhyolites, latites, and andesites. A broad, unsymmetrical syncline, pitching northward, with a steeply dipping west limb and a gently dipping east limb, traverses the mining district. The southern and eastern areas are largely covered with extensive masses of igneous rocks. Faulting and fissuring are prominent throughout the district. Predominant faults strike easterly or northeasterly. Four major north-trending vein zones are recognized in the district (fig. 2). Ore shoots, locally called "ore runs," of varying number, have developed on the vein zones. The Chief mine of the Chief Consolidated Mining Co. is the northernmost of a series of mines in the second zone from the west. A continuous zone of ore has been mined from the surface at the Mammoth mine to the lowest working of the Chief mine, a distance of 1-1/4 miles (fig. 3).

Ores of the Chief mine are found in the Gardner, Victoria, and Bluebell formations; the Bluebell dolomite has been the most important host rock. The main ore shoot starts high in the Bluebell dolomite at the Mammoth mine on the south and plunges slightly steeper than the northward pitch of the syncline through the vertical thickness of the Bluebell formation; it reaches its base approximately at the 2700 level of the Chief mine, where the formation is intersected by the Leadville fault dike. For many years it was believed that the ore shoot would terminate at the Leadville dike because of the unfavorable character of the underlying Opohonga formation as a host rock. The additional development has disclosed that the southdipping Leadville dike is a fault with reverse throw which has lowered the Bluebell dolomite in the footwall block the full thickness of the Bluebell formation (approximately 800 feet). The ore shoot passes through the dike with little displacement, continuing its course in the downfaulted block, high in the favorable Bluebell dolomite (fig. 3). The ore shoot also passes through a block of the Gardner formation between the Beck and Centennial faults, south of the Leadville dike.

Ore bodies are principally replacement-type deposits. They form along rolls or tears in bedding and as pipelike deposits on faults. High-grade masses or trends of ore are often encased in quartz pods or envelopes of lower grade material. The host rock is generally hard limestone and dolomite. Replacement of limestone by sphalerite and galena was virtually complete in the central part of the ore shoot, although

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3/ Tower, G. W., Jr., and Smith, G. O., Geology and Mining Industry of the Tintic District, Utah: Geol. Survey 19th Ann. Rept., 1898, pp. 601-767.

4/ Lindgren, W., and Loughlin, G. F., Geology and Ore Deposits of the Tintic Mining District, Utah: Geol. Survey Prof. Paper 107, 1919, 282 pp.

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some fragments of the host rock remain. Silver is present in all ores, and in some areas pods of ore with extremely high silver content have been mined.

EXPLORATION

Several thousand feet of drifts, crosscuts, and raises have been driven on the upper levels of the Chief and other mines in the district in searching for individual ore bodies. This work indicated the existence of specific mineralized zones, and development at greater depth was confined to pursuit of these zones. In the Chief mine diamond drilling is done primarily to locate the ore zones and thereby reduce costs by shortening the length of development drift or raise necessary to encounter the ore. Little attention is given to detailed delineation or grade of the ore body. Experience has shown that the ore shoots alter little in size or grade, although they wander and change dip as they are followed downward.

Generally development headings require little timber support. Short sections of drifts are sometimes timbered, especially when in major fault zones. Drifts are driven beneath the ore shoots, when possible, and raises are driven at convenient intervals into the ore.

SAMPLING AND ESTIMATION OF ORE RESERVES

There is little need for frequent detailed stope sampling because of the continuity of ore shoots and consistency of ore value. Samples are taken from the stopes as ore cars are loaded and check grab-samples are taken as the cars are hoisted. As the stope is advanced the foreman takes samples of low-grade faces to make sure all ore in the stope is mined. Samples are also cut in drifts, crosscuts, and raises in ore. All samples are delivered on the surface at the end of the shift.

Although diamond drilling is used primarily for locating ore shoots, the cores and sludges are saved for reference or assaying.

Eight classes of ore are shipped. The foreman, from experience, classifies the ores and takes grab samples for verification of the classification. Questionable ores are stored on a ramp until assay results are known and then trucked to the railroad. The bookkeeper determines which smelter or mill will receive the ore for the greatest monetary return to the company. The company may ship ores to any of 3 purchasers under 5 mill and smelter contracts.

Ore reserves are not blocked out in advance of development work. The method generally used to estimate reserves in an ore shoot is to combine the grade and tonnage of ore for the two 100-foot blocks immediately above the ore block to be developed with the average grade and tonnage of all known blocks above the lower 2 blocks. The final average is the estimated ore expected in the block to be developed.

GENERAL MINE OPERATION

The mine is operated from the surface through the Chief No. 1 shaft, a 3-compartment, vertical shaft 1,800 feet deep. Five auxiliary winzes have been sunk below the 1800 level. The 18-411 winze is the main working winze for development from the 1800 to the 3000 level (figs. 4 and 5). The Chief No. 2 shaft extends from the surface to the 1880 level and is used for ventilation. Power cables for the latest pumping system also are carried down this shaft. Drifts have been driven on the

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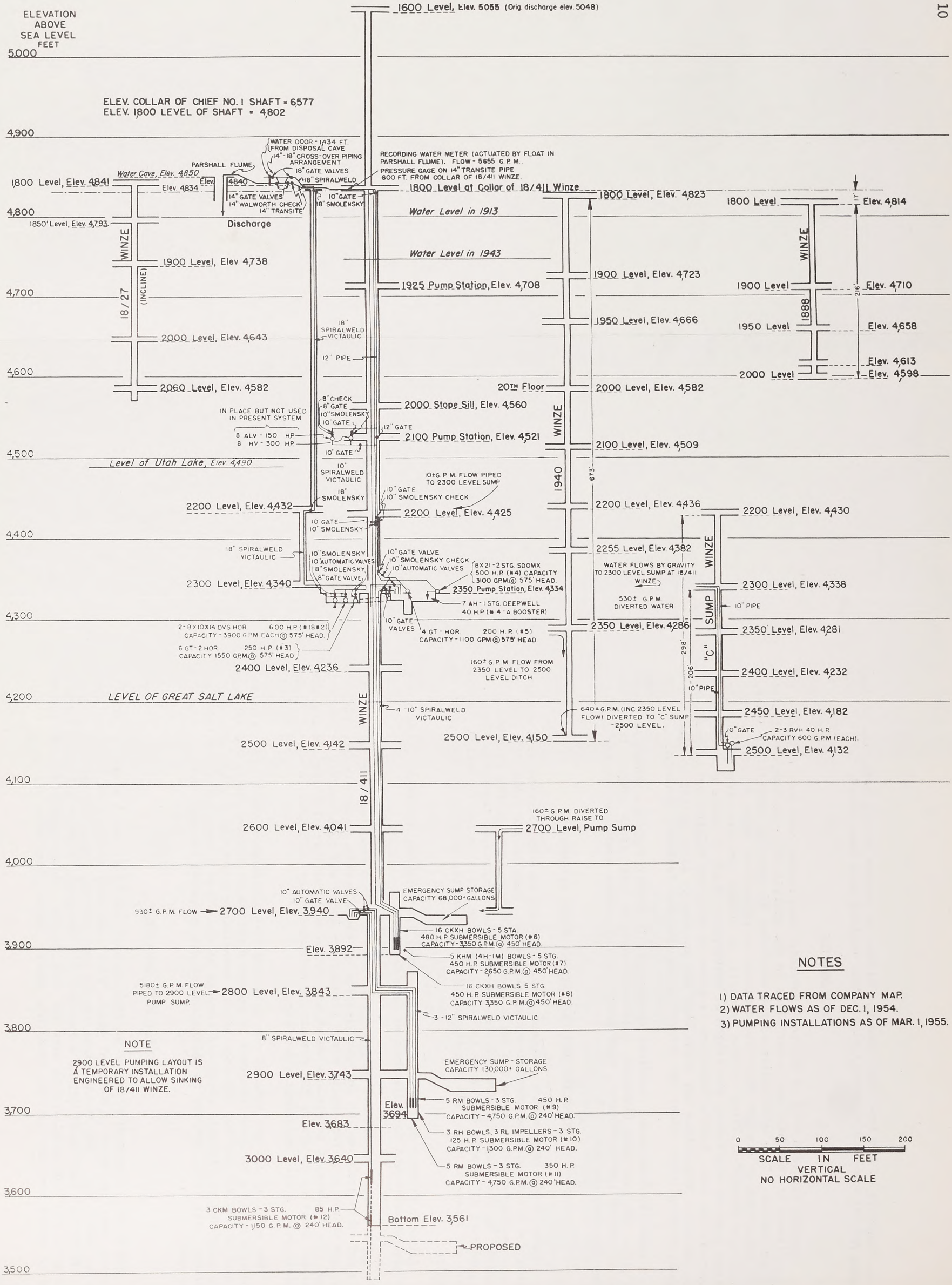
ELEVATION ABOVE SEA LEVEL FEET
5,000
4,900
4,800
4,700
4,600
4,500
4,400
4,300
4,200
4,100
4,000
3,900
3,800
3,700
3,600
3,500
1600 Level, Elev. 5055 (Orig. discharge elev. 5048)
ELEV. COLLAR OF CHIEF NO. 1 SHAFT = 6,577
ELEV. 1800 LEVEL OF SHAFT = 4,802
WATER DOOR - 1434 FT. FROM DISPOSAL CAVE
14"-18" CROSS-OVER PIPING ARRANGEMENT
18" GATE VALVES
18" SPIRALWELD
PARSHALL FLUME
Water Cave, Elev. 4850
1800 Level, Elev. 4841
Elev. 4834
Elev. 4840
14" GATE VALVES
14" WALWORTH CHECK
14" TRANSITE
10" GATE
18" SMOLENSKY
RECORDING WATER METER (ACTUATED BY FLOAT IN PARSHALL FLUME). FLOW - 5655 G.P.M.
PRESSURE GAGE ON 14" TRANSITE PIPE 600 FT. FROM COLLAR OF 18/411 WINZE.
1800 Level at Collar of 18/411 Winze
Discharge
1850' Level, Elev 4,793
WINZE
18/27
(INCLINE)
1900 Level, Elev 4,738
2000 Level, Elev. 4,643
2060 Level, Elev. 4,582
Water Level in 1913
Water Level in 1943
1925 Pump Station, Elev. 4,708
18" SPIRALWELD VICTAULIC
12" PIPE
IN PLACE BUT NOT USED IN PRESENT SYSTEM
8" CHECK
8" GATE
10" SMOLENSKY
10" GATE
8 ALV - 150 H.P.
8 HV - 300 H.P.
12" GATE
2100 Pump Station, Elev. 4,521
Level of Utah Lake, Elev. 4,490
10" SPIRALWELD VICTAULIC
18" SMOLENSKY
2200 Level, Elev. 4,432
10" GATE
10" SMOLENSKY
10±G.P.M. FLOW PIPED TO 2300 LEVEL SUMP
10" GATE
10" SMOLENSKY CHECK
2200 Level, Elev. 4,425
18" SPIRALWELD VICTAULIC
10" SMOLENSKY
10" AUTOMATIC VALVES
8" SMOLENSKY
8" GATE VALVE
2300 Level, Elev. 4,340
10" GATE VALVE
10" SMOLENSKY CHECK
10" AUTOMATIC VALVES
8X21-2 STG. 500MX 500 H.P. (#4) CAPACITY 3100 GPM @ 575' HEAD.
2350 Pump Station, Elev. 4334
7 AH-1 STG. DEEPWELL 40 H.P. (# 4-A BOOSTER)
2-8X10X14 DVS HOR. 600 H.P. (#18#21) CAPACITY - 3900 G.P.M. EACH @ 575' HEAD.
6 GT-2 HOR. 250 H.P. (#3) CAPACITY 1550 GPM @ 575' HEAD.
10" GATE VALVES
4 GT - HOR. 200 H.P. (#5) CAPACITY - 1100 GPM @ 575' HEAD.
2400 Level, Elev. 4,236
160± G.P.M. FLOW FROM 2350 LEVEL TO 2500 LEVEL DITCH
LEVEL OF GREAT SALT LAKE
4 - 10" SPIRALWELD VICTAULIC
2500 Level, Elev. 4,142
640± G.P.M. (INC 2350 LEVEL FLOW) DIVERTED TO "C" SUMP -2500 LEVEL.
2500 Level, Elev. 4,150
18/411
2600 Level, Elev. 4,041
160± G.P.M. DIVERTED THROUGH RAISE TO
2700 Level, Pump Sump
10" AUTOMATIC VALVES
10" GATE VALVE
930± G.P.M. FLOW
2700 Level, Elev. 3,940
EMERGENCY SUMP STORAGE CAPACITY 68,000+ GALLONS
16 CKXH BOWLS - 5 STA. 480 H.P. SUBMERSIBLE MOTOR (#6) CAPACITY - 3350 G.P.M. @ 450' HEAD.
Elev. 3,892
5 KHM (4H-1M) BOWLS - 5 STG. 450 H.P. SUBMERSIBLE MOTOR (#7) CAPACITY - 2650 G.P.M. @ 450' HEAD.
5180± G.P.M. FLOW PIPED TO 2900 LEVEL PUMP SUMP.
2800 Level, Elev. 3,843
16 CKXH BOWLS 5 STG. 450 H.P. SUBMERSIBLE MOTOR (#8) CAPACITY 3,350 G.P.M. @ 450' HEAD.
3 - 12" SPIRALWELD VICTAULIC
8" SPIRALWELD VICTAULIC
NOTE
2900 LEVEL PUMPING LAYOUT IS A TEMPORARY INSTALLATION ENGINEERED TO ALLOW SINKING OF 18/411 WINZE.
2900 Level, Elev. 3743
EMERGENCY SUMP - STORAGE CAPACITY 130,000+ GALLONS.
Elev. 3694
5 RM BOWLS - 3 STG. 450 H.P. SUBMERSIBLE MOTOR (#9) CAPACITY - 4,750 G.P.M. @ 240' HEAD.
Elev. 3683
3 RH BOWLS, 3 RL IMPELLERS - 3 STG. 125 H.P. SUBMERSIBLE MOTOR (#10) CAPACITY - 1,300 G.P.M. @ 240' HEAD.
3000 Level, Elev. 3640
5 RM BOWLS - 3 STG. 350 H.P. SUBMERSIBLE MOTOR (#11) CAPACITY - 4,750 G.P.M. @ 240' HEAD.
3 CKM BOWLS - 3 STG. 85 H.P. SUBMERSIBLE MOTOR (#12) CAPACITY - 1,150 G.P.M. @ 240' HEAD.
Bottom Elev. 3,561
PROPOSED
1800 Level, Elev. 4823
1900 Level, Elev. 4,723
1950 Level, Elev. 4,666
20TH Floor
2000 Level, Elev. 4,582
2000 Stope Sill, Elev. 4,560
WINZE
1940
673'
2100 Level, Elev. 4,509
2200 Level, Elev. 4,436
2255 Level, Elev. 4,382
2350 Level, Elev. 4,286
2450 Level, Elev. 4,182
2500 Level, Elev. 4,132
WATER FLOWS BY GRAVITY TO 2300 LEVEL SUMP AT 18/411 WINZE.
530± G.P.M. DIVERTED WATER
1800 Level
Elev. 4,814
17'
1900 Level
Elev. 4,710
216'
1888
1950 Level
Elev. 4,658
Elev. 4,613
2000 Level
Elev. 4,598
2200 Level, Elev. 4,430
2300 Level, Elev. 4,338
SUMP
10" PIPE
2350 Level, Elev. 4,281
298'
"C"
206'
2400 Level, Elev. 4,232
10" PIPE
10" GATE
2-3 RVH 40 H.P. CAPACITY 600 G.P.M. (EACH).
NOTES
1) DATA TRACED FROM COMPANY MAP.
2) WATER FLOWS AS OF DEC. 1, 1954.
3) PUMPING INSTALLATIONS AS OF MAR. 1, 1955.
0 50 100 150 200
SCALE IN FEET
VERTICAL
NO HORIZONTAL SCALE

Figure 4. - Sections of main winzes below water level.

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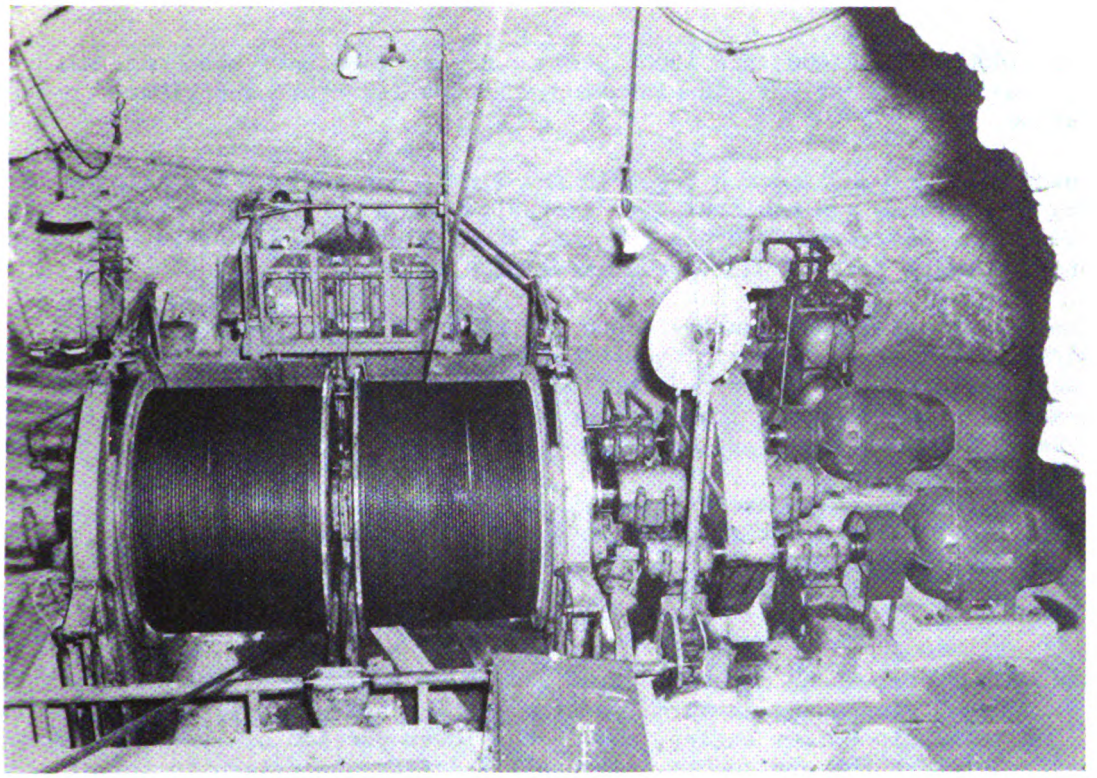

Figure 5. - Hoist installation at 1800 level, 18-411 winze.

Figure 6. - View of typical stope.

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600, 800, 1000, 1200, 1400, and 1800 levels. Connections have been made with other mines of the district at various elevations and levels; these contribute to the ventilation.

Loaded cars are hoisted on cages in the winzes and shaft. Three topmen dump the cars into trucks and haul the graded ores to ramps for loading directly into railroad cars. The waste is trucked to the dump. Battery locomotives are used to pull ore and waste cars on underground levels.

The company uses an incentive bonus system in which everyone engaged in production work participates. The employee receives a bonus, in addition to the regular daily wage, according to the number of cars handled. Thus, everyone from the miner in the stope to the topman at the shaft collar is concerned with the output. Each worker keeps records, which are compared with the daily total.

Ever-increasing costs are induced by many factors, principal of which are: (1) Rising pumping costs due to added head and (2) increasing distance of ore bodies from winzes and shafts (fig. 7).

MINING

The open-stope mining method is used almost exclusively at the Chief mine (fig. 6). Ore bodies occur in hard limestone, which needs little support. The stopes generally dip at low angles, and in the lower portion of the mine long drifts are required to cut the ore shoots. Generally, drifts are driven to permit scraping the ore from the stope into cars.

Several types of pneumatic drills are used. Jackhammers and stopers are utilized to drill the ores in the stopes, and 4-inch automatic drifters mounted on single-arm hydraulic jumbos are used in the headings. In some instances jackhammers supported by airlegs are used, but these are not popular with the miners because of the hard ground. Ores and waste are handled either with shovel loaders or scrapers. The company has 16 shovel loaders, 18 air scrapers, and 3 electric scrapers.

Drifts and crosscuts are 6 by 8 feet and raises 6 by 6 feet. Burn-cut rounds are drilled in the development headings. The common practice is to complete the cycle of a "round in and round out" per shift. The average drill round pulls 6 feet. In dry ground the drill holes are blasted with 40-percent-strength No. 2 Gelamite and in wet ground with 60-percent gelatin powder.

Drill steel is 1-1/8-inch round for drifters mounted on jumbos, 1-inch quarter octagon for stopers, and 7/8-inch hexagon for jackhammers on legs or for sinking. Bits for all sizes of steel are 2-3/4-inch tungsten carbide.

VENTILATION

The Chief No. 1 is an upcast shaft. In winter the Gemini mine shaft is used for downcast and in the summer the Chief No. 2 acts as a downcast shaft. Natural ventilation is supplemented by a 50-hp. fan with a capacity of 36,000 cubic feet per minute, installed on the 1800 level. The air is directed by a series of doors into the 18-411 winze; after being forced through this winze it passes into the lower workings and rises through the stopes and up the 1940 winze.

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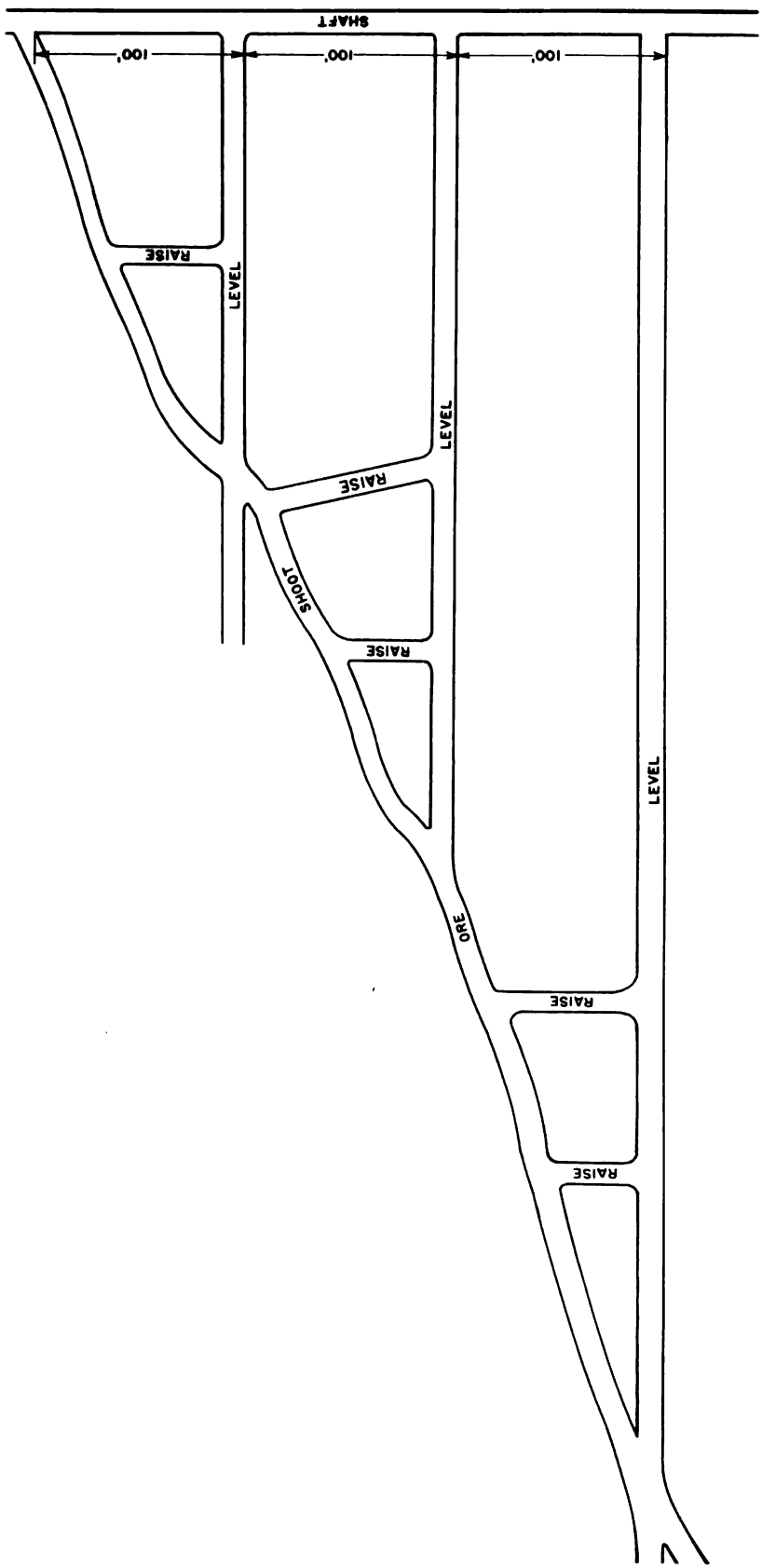

Figure 7. - Idealized section of mine workings.

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SHAFT SINKING

Sinking started in the 18-411 winze below the 2700 level in March 1952 under the DMEA program. The winze is in hard, massive Opohonga limestone, which yielded only 16 g.p.m. of water in the sinking operation. Most of this water came in at the bottom of the winze. The 18-411 winze is a 3-compartment opening from the 1800 to the 2700 level. It was considered desirable to have a 4-compartment winze below the 2700 level to carry on normal operations and to sink at the same time.

As an economy measure, a scheme was devised to sink, using a three-compartment winze. This was accomplished by discontinuing the compartment containing the waterlines at the 2700 level and starting a new third compartment at the opposite end of the winze. It was necessary to raise above the new compartment from the 2700 to the 2665 level and install a sinking hoist on the 2500 level. This procedure permitted the sinking operation to be conducted simultaneously with normal shaft operations servicing all levels for mining and development. Waste loaded in the bottom of the winze was transferred from the sinking hoist to the service hoist on the operating level above the bottom of the winze. The two central compartments were maintained for balanced hoisting, and the new third compartment was used for waterlines after sinking was completed and development lowered the water table. If the water is pumped in one lift to the 2300 level, it will be necessary to switch lines from one side of the shaft to the other at the 2700 level; or the stage system now in use may be continued when water is pumped from the 3000 level to the 2900 level sump; from the 2900 level to the 2700 level sump; from the 2700 level to the 2300 level sump; and from the 2300 level to the 1800 level discharge.

A problem of major importance is control of the large flow of water while sinking and development are being conducted below the water table. In case of mechanical or electrical failure, the safety of the crew working below the water table presents a serious problem. Soon after sinking operations were begun in 1952, a mechanical failure occurred. The company had constructed a pump sump on the 2700 level, into which the flow was diverted. This sump is 10 by 10 by 50 feet in size and was considered large enough to hold the flow approximately 5 minutes. A scheme was devised to funnel the overflow from the sump into an 8-inch column, which was being carried down 1 end of the shaft outside of timber.

While sinking operations were in progress, a pumphead broke, disrupting pumping operations and allowing the column of water above the pumps to drain back into the sump. The drain from the column, plus the inflow, filled the sump almost immediately, and water started pouring down the shaft. The 8-inch drain column down the shaft proved inadequate. The crew was forced to climb out through the water and was fortunate to be able to complete the climb without loss of life. As a result of this failure, it became evident that a larger sump would be necessary, and the company constructed an additional 16- by 45- by 11-foot sump to hold the flow long enough to permit a crew to escape. A similar safety sump was constructed on the 2900 level.

The 18-411 winze is 16.5 by 6.5 feet in rock dimensions, and 6- by 8-inch timber is used. It is divided into 3 compartments with 50 by 50 inches clearance inside timber in each compartment. Sets are spaced on 6-feet, 3-inch centers with bearing sets at each 100-foot level. Two compartments are used for hoisting and the third contains manway, water-pipe, air-pipe, and power lines.

A crew of 4 men works in the bottom during sinking operations; 1 of them acts as leadman. Each man is competent to do any job necessary in sinking, and each

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shift crew performs any type of work in the cycle. In other words, the crew continues the work left by the preceding crew, whether this work is drilling, mucking, or timbering.

Mucking is done with a clamshell hydromucker (fig. 8). The clamshell is constructed to permit hydraulic rams to close the jaws, and balanced counterweights cause them to open; it swings from a trolley that moves along a monorail stationed on sets above. The monorail is the length of two compartments. It is necessary to leave one divider out in the sets below the monorail to move the carriage along the winze. After the monorail is lowered, the dividers are installed. The clamshell swings manually into the third compartment and dumps on an Anaconda mucking pan and then into a car lowered on a cage in the third compartment. About 1 shift is required to muck out a 5-foot round. Electrically operated, hydraulic power units above the monorail activate the hydraulic rams on the clamshell. Air motors stationed on the monorail raise and lower the clamshell; these are operated by wires hanging in the shaft.

ELECTRIC POWER

Electric energy is purchased from the Utah Power & Light Co. at Eureka, Utah. Service is good, and power interruptions are rare. Electricity is delivered to a substation at Eureka at 44,000 volts. Here it is stepped down to 2 voltages - 4,160 and 2,300 volts. The 2,300-volt lines feed the old system (which is still intact) into the mine. The 4,160-volt lines feed the new system into the mine and are again transformed on the 2300 level to the voltage necessary for use in the new installation (fig. 9).

PUMPING SYSTEM

The main pumping station for the new system was excavated on the 2300 level (fig. 10) and is designed to be adequate for the maximum flow expected. The old pumping system also utilized a sump and pump station on the 2300 level. Although the new system is integrated with the old one near the point of outlet, it operates entirely independently. The old system remains intact and acts as a standby in case of emergency. Either will operate independently, or they can be operated simultaneously.

Figure 11 shows the 2300 level pumping-system arrangement. Pumps at this station boost the water to the 1800 level, where it is discharged into the Gemeni cavern. A sectional diagram of the pumping arrangement is shown on figure 4 (p. 10). Table 1 lists the pumps used and locations are shown on figure 11. Table 2 is a calculation of the water pumped per ton of ore mined.

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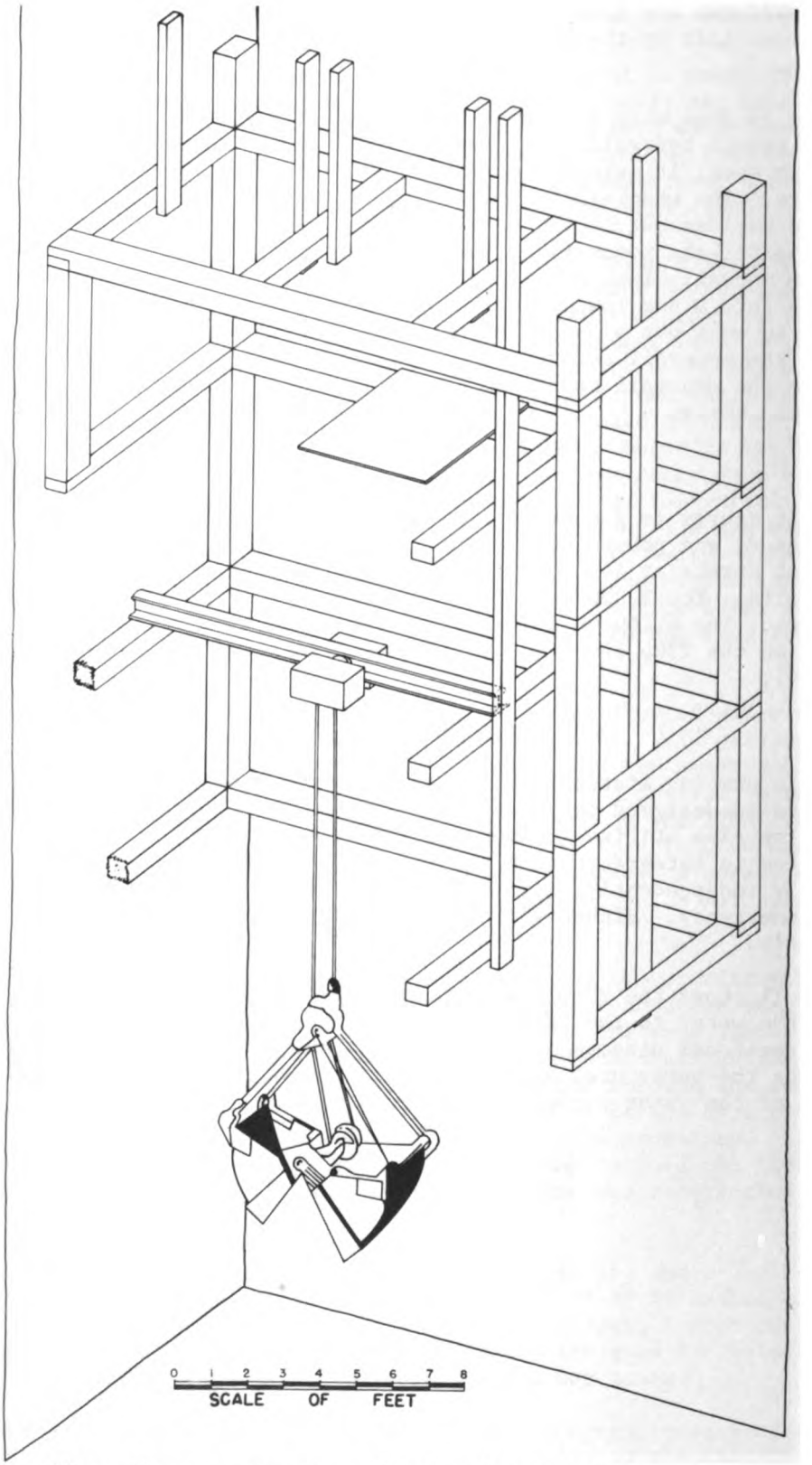

Figure 8. - Isometric view of hydro clamshell shaft mucker.

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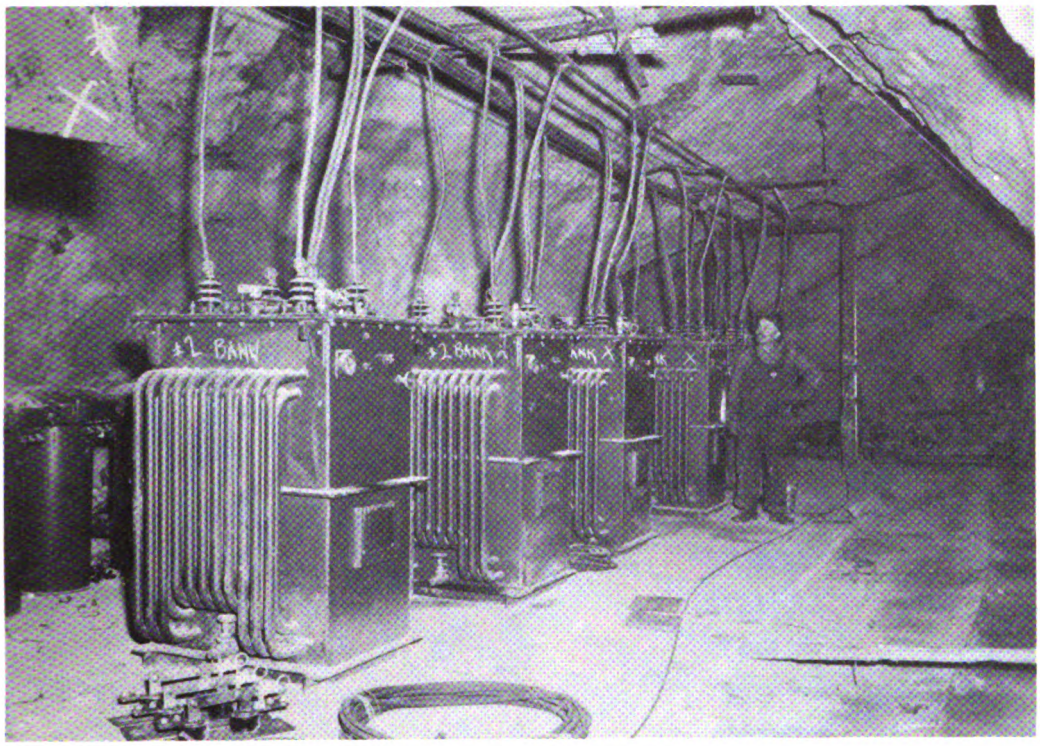

Figure 9. - View of transformer bank, 1800-level substation.

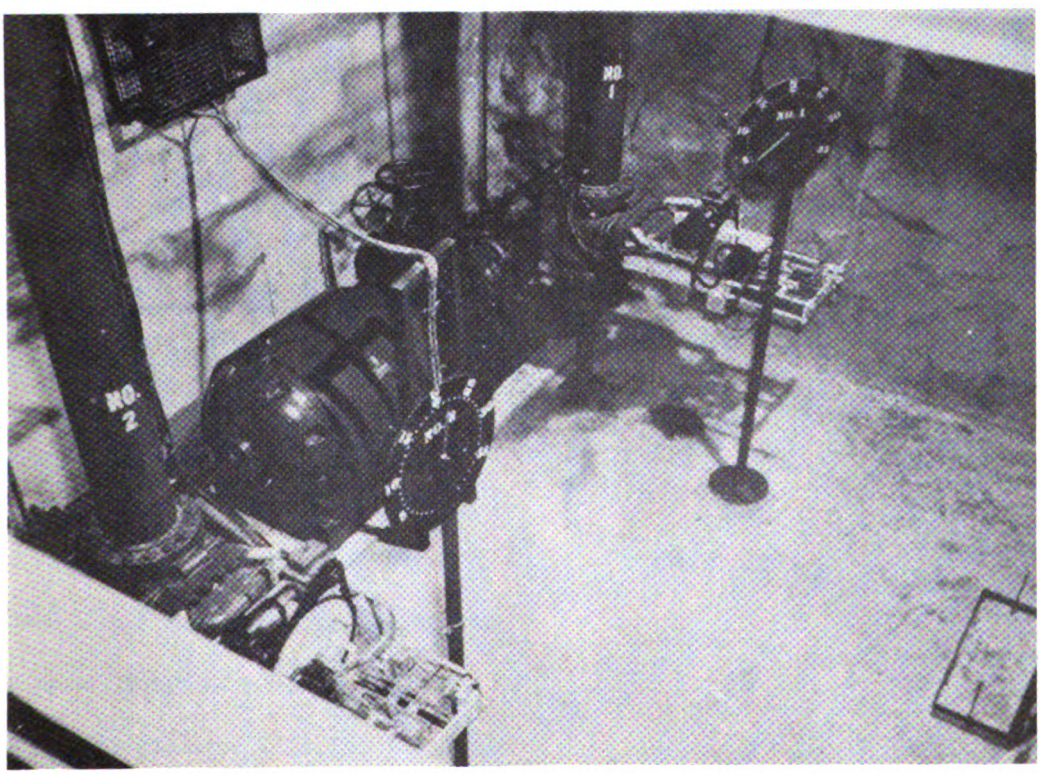

Figure 10. - View of pump station, 2300 level.

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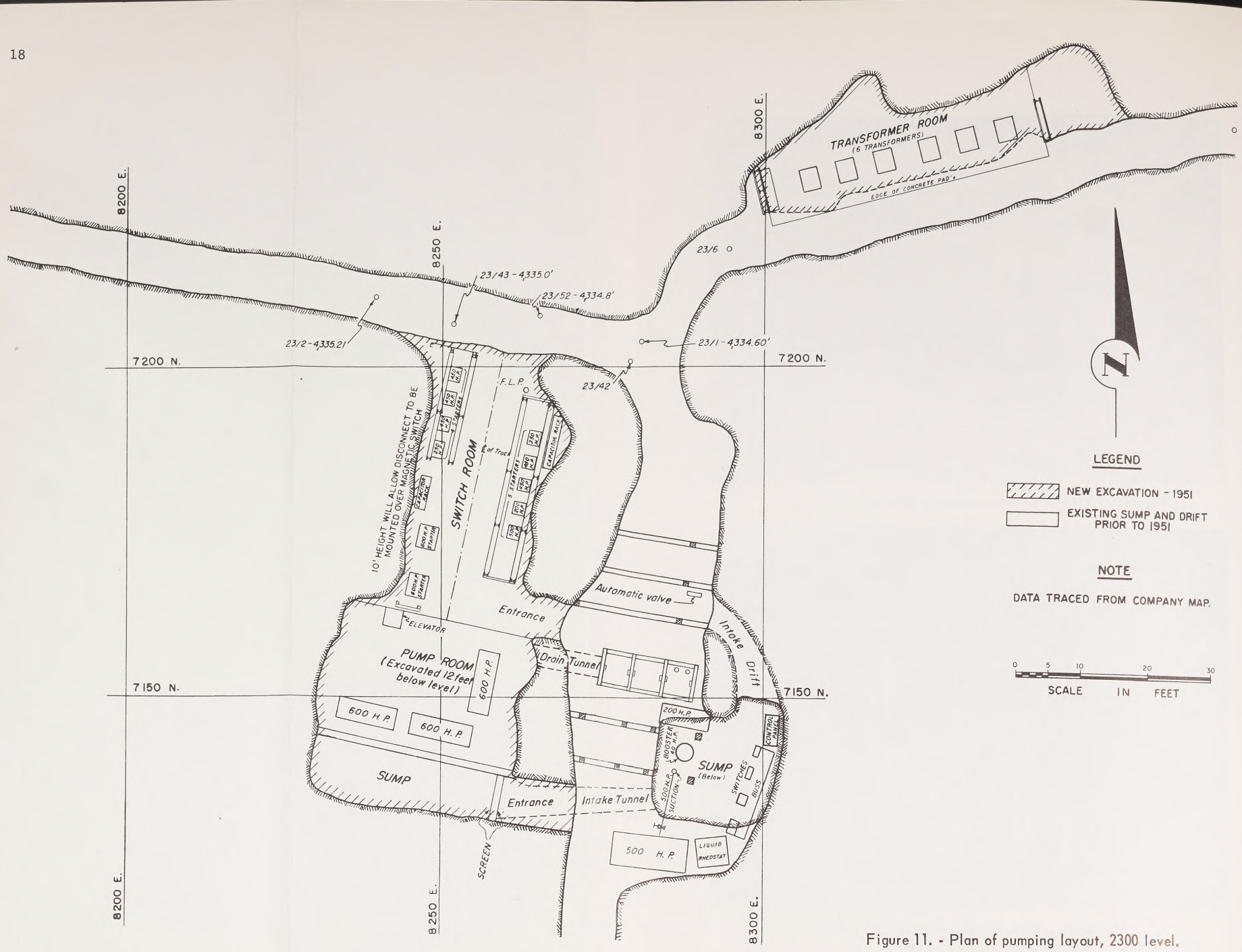

Figure 11. - Plan of pumping layout, 2300 level.

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TABLE 1. - List of pumps in the Chief mine

Pump No.	Type	Hp.	System	Rated capacity	Head, feet
	2300 level				
	Horizontal pumps				
1	8x10x14 DVS Byron-Jackson	600	New	3,900	575
2	8x10x14 DVS Byron-Jackson	600	do.	3,900	575
3	6-GT-2 Stg. Ingersoll Rand	250	do.	1,550	575
4	8x21-2 Stg. SDOMX Byron-Jackson	500	Old	3,100	575
4-A	7AH Deepwell Booster	40	do.	Booster for No. 4	
5	4-GT-2 Stg. Ingersoll Rand	200	do.	1,100	575
	2500 level				
	Horizontal pumps (in "C"-sump winze)				
X	3 RVH (2) Ingersoll Rand	40	Old	600	300
	2700-level sump				
	Vertical submersible pumps				
6	16CKXH-5 Stg. Byron-Jackson	450		3,350	450
7	5KRM-5 Stg. Byron-Jackson	450		2,650	450
8	16CKXH-5 Stg. Byron-Jackson	450		3,350	450
	2900-level sump				
	Vertical submersible pumps				
9	5 RM-3 Stg. Byron-Jackson	450		4,750	240
10	3 RH-3 Stg. Byron-Jackson	125		1,300	240
11	5 RM-3 Stg. Byron-Jackson	350		4,750	240
	Shaft (standby for dewatering in case of shaft flooding				
12	3 CKM-3 Stg. Byron-Jackson	85		1,150	240

TABLE 2. - Calculation of water pumped per ton of ore mined, June 1954

4,255 mine cars hoisted

4,255 x 1.1 (tonnage factor) = 4,680 tons

30 days in June x 24 hours x 60 minutes = 43,200 minutes

$\frac{4,680 \text{ tons}}{43,200}$ = 0.108 ton of ore per minute

Pumping rate, approx. = 6,500 g.p.m.

$\frac{6,500}{0.108}$ = 60,185 gallons (251.135 tons) pumped per ton of ore mined.

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COSTS

The costs incurred in December 1954 and for the year 1954 are summarized in tables 3 and 4. Costs of mining, especially for development and pumping, increase as the mine is advanced to greater depth. The operation is efficiently managed, and planning for mining at greater depth is done well in advance.

TABLE 3. - Summary of underground costs per ton, December 1954 and year 1954, based on tons of ore hoisted

	Labor	Compressed air, drill steel, and bits	Power	Explosives and timber	Other	Total
Development:						
Dec. 1954						$1.86
1954	$0.89	$0.17	$0.13	$0.35	$0.15	1.69
Stoping:						
Dec. 1954						5.15
1954	2.88	.43	.28	.48	.32	4.39
Transportation:						
Dec. 1954						1.00
1954	.45		.46		.02	.93
Pumping:						
Dec. 1954						1.35
1954	.79		.60			1.39
Surface expense applicable:						
Dec. 1954						.16
1954	.16		.04		.04	.24
Payment on DMEA assistance:						
Dec. 1954						.52
1954					.45	.45
Total Dec. 1954	-	-	-	-	-	10.04
Total 1954	5.17	.60	1.51	.83	.98	9.09

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TABLE 4. - Summary of indirect expenses and total cost per ton for December 1954 and year 1954, based on tons of ore hoisted

	December 1954	Year 1954
Indirect mining expense:		
Foremen and shaft bosses	$0.35	$0.29
Surveying and engineering	.14	.12
Geological advisory	.11	.06
General underground expense	.02	.06
Surface operating expense	.23	.18
Electric lights	.03	.02
Workmen's Compensation and Insurance	.21	.22
Watchman	.04	.05
Joint water account	.01	.01
Overtime and payroll fringe account	.52	.40
Total	1.62	1.41
Overhead and administrative expense:		
Presidency and general management	$0.22	$0.25
Mine dwellings	.08	.09
General expense	.20	.37
Auto expense	.01	.03
Fire and liability	.05	.04
Accounting	.05	.06
Salt Lake office	.09	.08
Mine office	.12	.12
Telephone	.02	.02
Employees' group insurance	.10	.12
Legal expense	.03	.02
Social Security and payroll tax	.04	.14
Property and sundry tax	.17	.18
Rent collections	.03	.05
Retroactive wages	.08	.08
Total	1.23	1.55
Total operating cost	12.89	12.05

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